G. J. HINDE'S (1899) DEVONIAN RADIOLARIANS FROM TAMWORTH, NORTH-EASTERN NEW SOUTH WALES: STRATIGRAPHIC AND CHRONOLOGIC CONTEXT

RUTH MAWSON[1], DEREK PANG[2] & JOHN A. TALENT[1]

[1]Centre for Ecostratigraphy and Palaeobiology, School of Earth Sciences, Macquarie University, New South Wales 2109, Australia

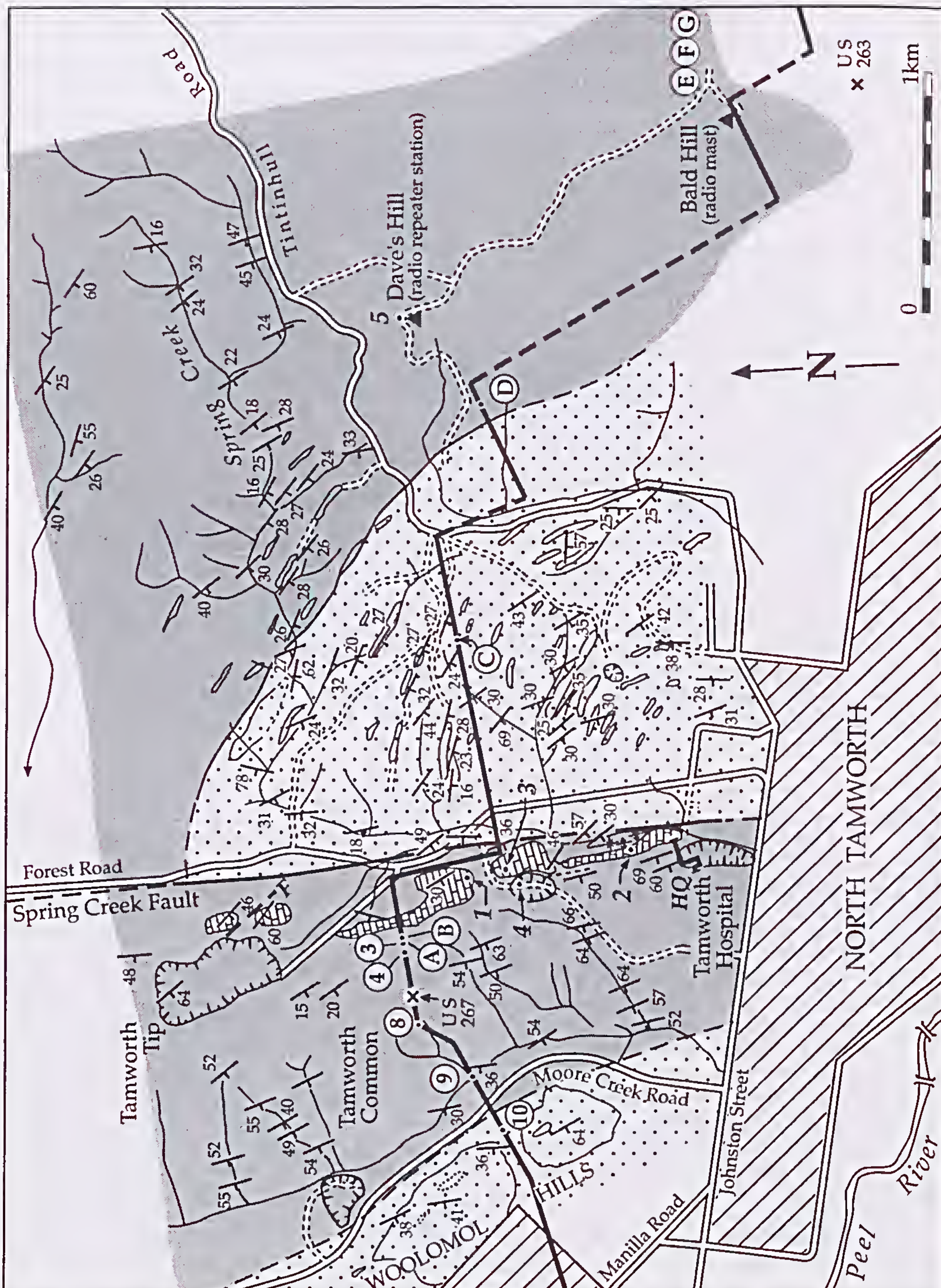
[2]Department of Applied Geology, University of Technology Sydney, PO Box 123, Broadway, New South Wales 2007, Australia

MAWSON, R., PANG, D. & TALENT, J. A., 1997:12:31. G. J. Hinde's (1899) Devonian radiolarians from the Tamworth area, north-eastern New South Wales: stratigraphic and chronologic context. *Proceedings of the Royal Society of Victoria* 109(2): 233–256. ISSN 0035-9211.

David & Pittman (1899) obtained Devonian radiolarians described by Hinde (1899) and revised by Aitchison & Stratford (1997) from the North Tamworth area of NE New South Wales. The host sequence is primarily fine-grained turbidites with minor horizons of debris-flow limestones, arenites, and thin ashfalls. The largest limestone bodies, formerly referred to as the 'Spring Creek limestone', are interpreted as olistoliths of Moore Creek Limestone emplaced during accumulation of the upper part of the Yarrimie Formation. Because of the demonstrably allochthonous nature of all limestones in the North Tamworth area, the conodont data from these olistoliths and from other limestones in that area are not tightly constraining as to chronology of the associated radiolarian horizons. The limestone horizons on David & Pittman's (1899) transect span an interval from early Emsian to late Frasnian and conceivably as young as the early Famennian–mid Famennian boundary (Late *rhomboidea* Zone to Early *marginifera* Zone). The taxonomically useful radiolarians (Aitchison & Stratford 1997) came from three horizons within the upper Yarrimie Formation. These horizons, stratigraphically above the olistoliths of 'Spring Creek limestone' (derived from Moore Creek Limestone, *australis* to *hemiansatus* Zones and perhaps Early *varcus* Subzone: late Eifelian–early Givetian), are argued to be late Givetian (*hermanni* Zone or younger) and late Frasnian respectively. A broader spectrum of mid-Palaeozoic ages (Pridoli to late Famennian) is indicated by conodonts occurring in association with radiolarians in cherts and siltstones from elsewhere in the region.

THE FIRST substantial investigation of the geology of the North Tamworth–Spring Creek area was by T. W. E. David and E. F. Pittman who constructed a detailed section extending some 7 km across this and adjoining areas (David 1896; David & Pittman 1899). Fossiliferous materials they collected were sent to G. J. Hinde and R. Etheridge, Jnr. Etheridge (1899) identified 19 species of corals from the 'Spring Creek limestone' and from adjacent limestone occurrences at Moore Creek and 'Moonbi' (see below). In a now classic paper, Hinde (1899) identified 53 species of radiolarians assigned to 29 genera from samples of black chert, limestone, claystone and tuffs from railway cuttings at Tamworth and, most importantly, from the Tamworth Common, an area extending northwards from the Tamworth Hospital and the adjacent Tamworth Hospital Quarry (Fig. 1).

As part of a much larger undertaking, W. N. Benson (1915) mapped the North Tamworth–Spring Creek area, recognising two stratigraphic sequences: an older or Tamworth Series (now Tamworth Group) considered to be Middle Devonian, overlain by a Late Devonian sequence, the Baldwin Agglomerates (now Baldwin Formation). Benson concluded that the 'Spring Creek limestones' were the same age as the Moore Creek Limestone *c.* 8 km to the N. His mapping was subsequently extended southwards to Loomberah (Benson 1918; Cawood 1980; Furey-Greig 1995), and northwards—to Attunga, Sulcor and Yarramanbully (Benson 1917; Brown 1942; Chappell 1961; White 1964, 1965; Pedder 1967, 1968; Marshall 1968; McMinn 1977, 1982; Pohler & Herbert 1993; Pohler, manuscript). These areas have been foci of studies of carbonate petrology (Pohler & Herbert 1993; Pohler, manuscript) and the chronologic implications of conodont data obtained from autochthonous and allochthonous limestones (Mawson & Talent 1994a; Mawson et al. 1995, 1996; Furey-Greig 1995; Klyza 1995), but they do not cover the North Tamworth–Spring Creek–Seven Mile Creek



Tintinhull Road
Spring Creek
Dave's Hill (radio repeater station)
Bald Hill (radio mast)
US 263
1km
0
N
Forest Road
Spring Creek Fault
Tamworth Tip
Tamworth Common
US 267
HQ
Tamworth Hospital
NORTH TAMWORTH
Moore Creek Road
Johnston Street
Manilla Road
WOOLOMOL HILLS
Peel River

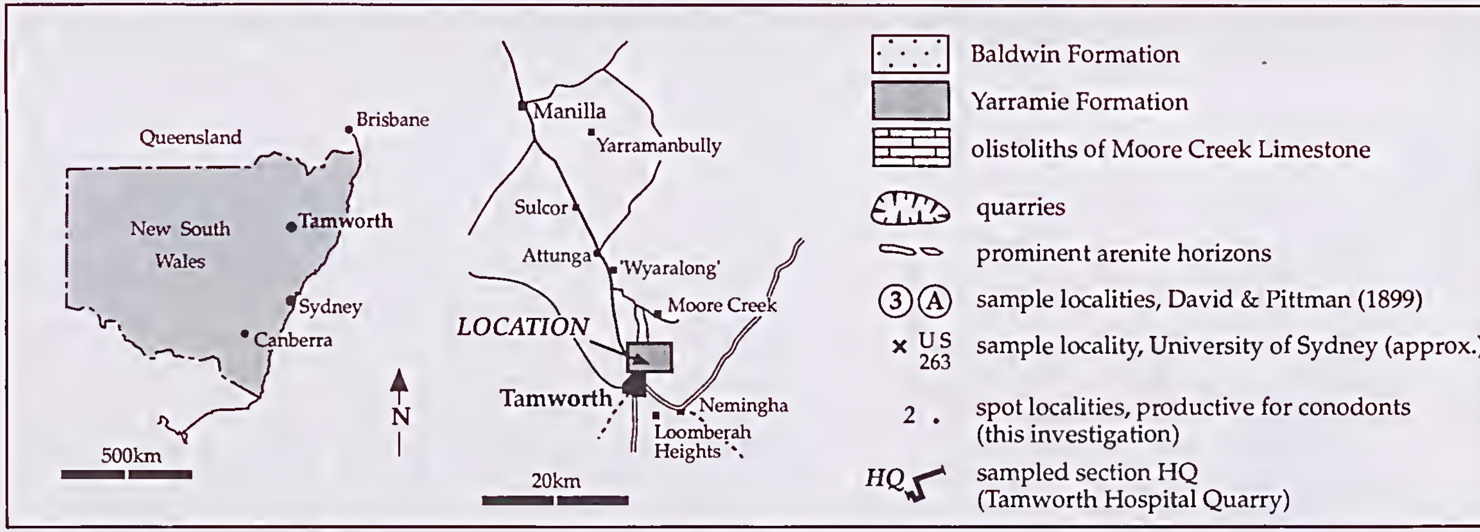


Fig. 1. Geology of the North Tamworth–Spring Creek area, New South Wales, showing the western part of David & Pittman's (1899) sampled section-line as well as the position of their localities, the Tamworth Hospital Quarry section (HQ), and other localities that have proved productive for conodonts.

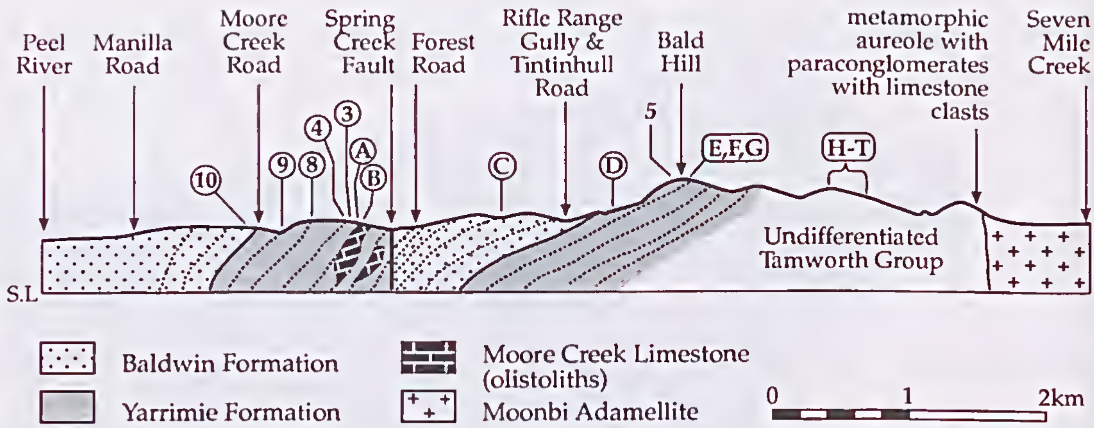


Fig. 2. Diagrammatic section following approximately the alignment of David & Pittman's (1899) North Tamworth section (natural scale). David & Pittman localities are shown circumscribed; locality 5 is a new locality. Other new localities 1–4 and the Hospital Quarry section have not been projected along strike onto the section line. Note that the section extends beyond the area shown in Fig. 1, from Bald Hill to the western flank of the Seven Mile Creek watershed where limestone cobble horizons occur in the metamorphic aureole marginal to the Moonbi Adamellite; these are suggested to represent the Drik Drik Formation or possibly the Silver Gully Formation. This interval is thought to be a repetition of David & Pittman's (1899) horizons H to T.

area, though it was included by Crook (1961a, 1961b, 1964) in a broad-scale synthesis of the geology of the Tamworth–Nundle–Timor area. Crook's work included a major rationalisation of stratigraphic nomenclature, and presentation of much new data on sedimentation. This work was extended by Pedder (1967) and Ellenor (1975). The areas considered in this report form part of what has been traditionally referred to as the Tamworth Belt. It has also been referred to as the Gamilaroi Terrane (Aitchison & Flood 1995, *q.v.* for earlier literature) and viewed as having sutured with 'cratonic' eastern Australia during the Late Devonian (Aitchison & Flood 1992).

Radiolarians have been documented from a scatter of localities through the Tamworth Belt (Hinde 1899; Aitchison et al. 1992, in press; Dongal 1995; Aitchison & Stratford 1997; Metcalfe et al. 1997; Stratford & Aitchison 1997) Corals have been described from the Moore Creek Limestone at North Tamworth and adjacent areas (Etheridge 1899; Hill 1942; Brühl & Pohler, manuscript) and from approximately coeval limestones farther afield at Timor (Pedder et al. 1970). Sponges have been described from Devonian limestones of the Tamworth Belt (Pickett 1969; Pickett & Pohler 1993). Stringocephalid brachiopods, characteristic of late Eifelian and Givetian rocks were noted almost a century ago from temporal equivalents of the Moore Creek Limestone at Crawney, S of Tamworth (Dun 1900: 195) and were documented subsequently from the Moore Creek Limestone at Sulcor (Brown 1944), 20 km N of the area under consideration.

All but two of David & Pittman's (1899) localities from which they obtained radiolarian-bearing Devonian sediments fall within the Tamworth Group (Fig. 1). The two exceptions, neither of these produced taxonomically useful radiolarians, are their localities C and 10; both are in the overlying Baldwin Formation. Horizons in the eastern (stratigraphically lower) part of their E-W section, in the Seven Mile Creek area, E of the area shown in Fig. 1, are from low in the Tamworth Group (see below); this interval is now well constrained by conodont data from elsewhere in the region (Mawson & Talent 1994a; Mawson et al. 1995; Furey-Greig 1995). According to Aitchison & Stratford (1997), the taxonomically useful material in the samples David & Pittman sent to Hinde came exclusively from 'radiolarian limestones 3 and 4' [samples 47 (3–4), HD4 and 45 (3)] low in the Yarrimie Formation [stratigraphically above David & Pittman's localities B and A; cf. Fig. 1] and from David & Pittman's horizon D [sample 387D] in the uppermost part of the Yarrimie Formation about 1.7 km E of the Spring Creek Fault (Fig. 1).

STRATIGRAPHIC CONTEXT

1. *Lower Tamworth Group Units* (area E of Fig. 1)

David & Pittman's (1899) section extended *c.* 2.3 km ENE from Bald Hill, beyond the area shown in Fig. 1, to the margin of the Moonbi Adamellite, just W of which is a belt of clastics with metamorphosed limestone clasts (David & Pittman 1899, horizons H to T). This belt falls within an area currently referred to as 'Seven Mile Creek Formation' (Crook 1961a) which is aligned with and lithologically resembles the Drik Drik Formation of the Nemingha–Piallamore area E of Tamworth (cf. Furey-Greig 1995). The latter area also has debris-flow deposits with abundant limestone clasts of early Emsian age, not older than *dehiscens* Zone (Furey-Greig 1995). Though our sampling of the Seven Mile Creek sequence along the alignment of David & Pittman's section, and N of it in allotment 173 parish of Moonbi, failed to produce conodonts, we suggest from the above that David & Pittman's horizons H to T are probably early Emsian in age, ie. considerably older than the limestone intervals of the Spring Creek area N of Tamworth. If equivalents of the post-Drik Drik/pre-Yarrimie units of the Tamworth Group—namely the Northcotte Formation, Wogarda Argillite and Silver Gully Formation—are indeed present along the eastern part of David & Pittman's section line, then these must be represented exclusively by clastics.

An alternative explanation is that these horizons H to T of David & Pittman (1899) are approximate equivalents of the late Emsian Silver Gully Formation. At Loomberah Heights, 16 km SE of Tamworth, the basal Silver Gully Formation, typically infested with debris flows with limestone clasts, has been shown from a thin autochthonous limestone interval to be very late Emsian—*serotinus* Zone or possibly *patulus* Zone, though the definitive form *Polygnathus costatus patulus* was not obtained (Mawson et al. 1995: 422). Limestones of approximately the same age are remarkably widespread within the Tamworth Belt, occurring in allochthonous blocks in the Bog Hole Formation on the island in Chaffey Dam 34 km SE of Tamworth (Mawson & Talent, unpubl. data), and in limestones an uncertain distance above the base of the Silver Gully Formation on the upper Barnard River near 'Chittick', about 55 km SE of Tamworth (Allen & Leitch 1992). Co-occurring *Polygnathus serotinus* and *P. costatus patulus* at the latter locality confirm a horizon early in the *patulus* Zone (Mawson et al. 1995: 424), ie. not far below the Emsian–Eifelian boundary. Approximately the same horizon has been reported from an autochthonous limestone-shale sequence at Bralga Tops on 'Glenrock' Station (Metcalfe et al. 1997), *c.* 75 km SE of Tamworth. At 'Chittick', the Silver Gully Formation is overlain by the Folly Spilite and, at least in that area, the onset of volcanism seems to have occurred close to the Emsian–Eifelian boundary. The Pitch Creek Volcanics (early Emsian) of the Pigna Barney area, *c.* 95 km SE of Tamworth, proven from conodonts from the overlying Bennys Tops Limestone (Dongol 1995) to be early Emsian *dehiscens–perbonus* Zones or older, are therefore interpreted as a volcanic episode significantly pre-dating the Folly Spilite.

The broad 'Silver Gully' interval referred to above is represented by the presently unnamed (L. Salem, unpubl. data) clastic sequence with minor limestones intervening between the Sulcor and Moore Creek Limestones in the Sulcor and Yarramanbully areas 25–35 km NW of Tamworth (S. Pohler, in prep.); conodont data (Mawson et al. 1996, 1998; Mawson & Talent, in prep.) suggest that this interval spans the Emsian–Eifelian boundary. Conodont data are already published for portion of this interval from the Attunga area, 18 km NW of Tamworth, by Mawson & Talent (1994a). Their section WY at 'Wyaralong', up to and including their sample WY148.5, includes debris flows with large limestone clasts. If the age indicated by conodonts from these clasts approximates the age of the enclosing sediments, this interval may equate with some of the upper part of the Silver Gully Formation. The presence of *Polygnathus costatus partitus* and *P. angustipennatus* from cobbles from sample WY91–96 is indicative of earliest Eifelian *partitus* Zone. The presence of *P. costatus costatus* c. 16 m stratigraphically higher in the WY section in sample WY 139, still in allochthonous limestone clasts, indicates the *costatus* Zone. This is about 15 m stratigraphically below the base of the Moore Creek Limestone. The *costatus* Zone is not known from any occurrences of Moore Creek Limestone, though Mawson & Talent's (1994a) samples OKE 62.9 and their Loc 1 in nodular limestones and siltstones low in the Moore Creek Limestone are indicative of an interval that spans broadly the upper third of the *costatus* Zone into the *australis* Zone. The 'Silver Gully' interval or 'unnamed formation' or 'lower Yarrimie Formation' (Pohler & Herbert 1993; Mawson & Talent 1994a) thus includes part and conceivably all of the *costatus* Zone. We suggest that, until such time as firm evidence to the contrary might be forthcoming, the base of the Moore Creek Limestone should be provisionally drawn at the *costatus–australis* boundary.

2. Moore Creek Limestone

Large bodies of Moore Creek Limestone outcropping in the watershed of Spring Creek, North Tamworth (Fig. 1), earlier referred to informally as the 'Spring Creek limestone', consist of buff grey to dark grey fossiliferous waekestones and grainstones, occasionally stylolitie. Rugose and especially tabulate eorals are relatively common in these as well as in all other occurrences of Moore Creek Limestone. The rugose eorals *Dohmophyllum* sp., *Xystriphyllum mitchelli* (Etheridge), *'Campophyllum'* cf. *lindstroemi* (Frech), *Disphyllum robustum* (Etheridge), *Phacellophyllum porteri* (Etheridge) and *Sanidophyllum davidis* Etheridge have been reported (Hill 1942) from the 'Tamworth Common, 1 mile north of Tamworth'. All of the above forms, except the first, are known from what we take to be the stratotype for the Moore Creek Limestone, immediately S of the hamlet of Moore Creek, or from other stratigraphically equivalent outerop-traets N of Tamworth. There can be little doubt, therefore, on the basis of rugose eorals, that aeeumulation of the 'Spring Creek limestones' was coeval with the Moore Creek Limestone *sensu stricto* and should bear the same stratigraphic name.

Etheridge's eoral colleetions, ineidentally, included materials labeled 'Woolomol limestone'. These are believed by us to be from the typical Moore Creek Limestone outeropping boldly in the reserve on the S side of Moore Creek (in the parish of Woolomol) opposite the hamlet of Moore Creek. Areas of limestone outerop farther S extend from the parish of Woolomol into the adjoining parish of Moonbi and are thought to be the source of old eolleetions labeled 'parish of Moonbi'.

An age-range *kockelianus–ensensis* zones for at least part of the Moore Creek Limestone at Moore Creek follows from re-interpretation (Mawson & Talent 1994a: 45) of conodonts documented by Philip (1966a). The presenee of the *australis* and *kockelianus* in the Moore Creek Limestone at Yarramanbully was demonstrated by Sloan (in Mawson et al. 1989: 500). The same interval, but with extension up into the *ensensis* Zone *sensu lato* [ie. without clear discrimination between *hemiansatus* Zone and the brief unnamed latest Eifelian post-*kockelianus* interval] was reported by Mawson & Talent (1994a) from the 'Wyaralong' outerop-tract at Attunga, 11 km NW of the stratotype at Moore Creek. The *australis–hemiansatus* zones have also been reported from a small, partly fault-bounded, antielinal oecurrence of Moore Creek Limestone at 'Warrawilla' 4.5 km E of Attunga (Klyza 1995).

Despite large parts of the North Tamworth–Spring Creek area lacking outerop, the following observations may be made regarding the limestones of that area:

1. The limestone tract does not map out as a coherent body, but as 5 major and apparently diserete bodies of limestone 130 to 600 m in length with, despite paucity of outcrops, evidence of intervening Yarrimie Formation sediments.
2. The two northernmost bodies appear to be diseordant to the strike of adjaeent Yarrimie Formation clastics, though this could be due to local flexure or fault displaeement as Benson (1915) suggested.
3. The top of the Moore Creek Limestone (sample HQ 0 on our Hospital Quarry seetion) produced a sparse conodont fauna indicative of the *kockelianus* Zone, revealing the absence of horizons expeeted high in the Moore Creek Limestone, namely the brief 'rump *ensensis*' Zone [after excision of the *hemiansatus* Zone], the *hemiansatus* Zone and possibly some of the Early *varcus* Subzone.
4. Additionally and importantly, the 5 bodies of Moore Creek Limestone are conspicuously devoid of the 'transitional intervals' above the Moore Creek Limestone, well expressed at Attunga, Suleor and Yaramanbully (Pohler & Herbert 1993; Mawson & Talent 1994a, unpubl. data; Pohler, manuscript).

We eonclude that the Moore Creek Limestone oeeurrenees in the Spring Creek area are olistoliths, dislodged after lithification, that have become ineorporated downslope in clastics of the Yarrimie Formation.

3. Yarrimie Formation

The Yarrimie Formation, the uppermost unit of the Tamworth Group, eonsists of 880 m or more (Crook 1961a) of typieally colour-banded dark grey to blaek and white argillites, often of eherty appearanee and containing radiolarians, with subordinate cream to white feldspathic ashfalls (relatively quartz poor), minor beds of lithic sandstone, particularly in the upper part of the formation, and uncommon intervals of conglomeratic limestone with pebble- to cobble-sized clasts of various limestone lithologies, mudstone and, rarely, igneous rocks. Exposures, although generally poor, are excellent in the quarries of the North Tamworth area.

No unequivocally autochthonous limestones were encountered in the Yarrimie Formation of the North Tamworth area; almost all are pebble- or cobble-sized clasts in conglomerates, though larger isolated clasts, rarely exceeding a cubic metre in size, have been encountered during quarrying in the Tamworth Hospital Quarry. Autochthonus limestone horizons nevertheless occur low in the Yarrimie Formation elsewhere in the Tamworth Belt, eg. at Sulcor (Mawson & Talent, in prep.) and Attunga (Mawson & Talent 1994a). In the latter area, Early and Late *varcus* zones (and by inference Middle *varcus* Zone) have been demonstrated in the interval of limestones and clastics transitional to the Yarrimie Formation immediately overlying the Moore Creek Limestone at Attunga. The Moore Creek Limestone was thus demonstrated to be 'sandwiched' between the *costatus* Zone (below—see earlier) and the Early *varcus* Zone above, but with the possibility of it including minor intervals referable to one or both of these zones.

4. *Baldwin Formation*

The Baldwin Formation (Crook 1961b) has not been a principal focus of the present investigation. It consists of 945 m or more of massive, medium to coarse grained, thick bedded, green-grey feldspatho-lithic arenites with interbeds of thinly bedded sandstone and siltstone. Its lower boundary is gradational from the underlying Yarrimie Formation. Famennian conodonts (Late *rhomboidea* Zone to Early *marginifera* Zone) have been reported (Marshall 1968; McMinn 1977, 1982) from limestone horizons at two localities in the Yarramanbully area (see below); conodonts and radiolarians of somewhat younger Famennian age (*postera* to Early *expansa* Zones) have been reported (Naka et al. 1988) from outcrops in the Peel River about 3 km downstream from Nundle.

SAMPLING OF THE NORTH TAMWORTH AREA

An attempt was made to locate and sample all limestone horizons on David & Pittman's (1899) section as well as other limestone horizons in the North Tamworth area, including the sequence exposed along the N face of the Tamworth Hospital Quarry. The latter section has excellent exposures and equates fairly well with the poorly exposed sequence immediately above the 'Spring Creek limestone' along David & Pittman's (1899) section line through their horizons B, A, 3 and 4 in ascending order stratigraphically (Fig. 1). Their horizon B equates approximately with the Tamworth Hospital horizon HQ 1 and, of special importance as regards radiolarians figured by Aitchison & Stratford (1997), David & Pittman's horizon 3 equates approximately with HQ 4, and their horizon 4 either with HQ7 or a somewhat higher horizon now covered by quarry fill.

David & Pittman's horizon D, also of significance for radiolarians, is inferred to correlate with a horizon high in the upper Yarrimie Formation possibly with their horizon 9 or between it and locality 10 (low Baldwin Formation, Fig. 1). If this assumption is correct, horizon D would be *c.* 470–500 m stratigraphically above David & Pittman's horizon 3.

Limestones E, F and G of David & Pittman,, on Bald Hill, failed to produce conodonts, but one horizon (M&T 5, Fig. 1) among what is inferred to be the same swarm of conglomeratic limestones along strike near the radio repeater station on Dave's Hill (Fig. 1), *c.* 200–240 m below the base of the Baldwin Formation, produced broken, unidentifiable conodonts. A lithologically similar group of conglomeratic limestones in the vicinity of David & Pittman's locality 8, recently exposed by bulldozing during tree-planting and fencing, is thought to represent a repeat of the Dave's Hill and Bald Hill conglomeratic limestones; these failed to produce conodonts.

David & Pittman's stratigraphically highest limestone, at locality 10 just W of the Moore Creek Road (Fig. 1), consists of fist-sized limestone cobbles in arenites, and irregular, poorly defined patches of calcareous arenite, very low in the Baldwin Formation. These limestones failed to produce conodonts.

NOTES ON CONODONTS AND THEIR CHRONOLOGIC IMPLICATIONS

1. *North Tamworth area*

Most sampled horizons in this area gave low yields (Fig. 1) or proved barren of conodonts. Conodonts (Table 1) from clasts from the various limestone-bearing horizons, and isolated clasts in the Yarrimie Formation exposed in the Tamworth

Formation		Moore Creek Limestone						Yarrimie Formation								
Conodont taxa \ Sample No.		near D&P-A	near D&P-B	M&T-1	M&T-2	M&T-3	HQ 0	HQ 1	HQ 1 (loose)	HQ 2	HQ 2A	HQ 3A	HQ 4	HQ 5	HQ 6	HQ 7 (loose)
Belodella resima			10	9	4		2	2	1	1	3			1	1	1
Drepanodus sp.					2				1		1				1	
Dvorakia sp.									1							
Icriodus struvei																1
Neopanderodus aequabilis										1				1	1	2
Neopanderodus sp.														1		
Panderodus unicostatus		1			4		2		1		1					2
Polygnathus aequalis									1							
Polygnathus cooperi cooperi														1		
Polygnathus cristatus											1					
Polygnathus hemiansatus													2		1	
Polygnathus linguiformis linguiformis														1	1	1
Polygnathus linguiformis klapperi											1					
Polygnathus cf. *ovatinodosus*											1					
Polygnathus pennatus									1							
Polygnathus xylus xylus									1		1		2			
Polygnathus sp. A				1												
Polygnathus sp.		2		1								1				
Prioniodina sp. A	Pa					1										
	Pb					2										
	Sb					1										
	Sc					3										
Tortodus kockelianus kockelianus							2									
Unassigned elements	Pa	2		1				1			1					
	Pb	2	2	4							1	1	1			2
	M	1										1				
	Sa							1								
	Sb	3		2				2			1					
	Sc	5	2	2			3	1	1		2	1	1	3		2

Table 1. Distribution of conodonts, arranged stratigraphically, from measured stratigraphic section across the back/north) wall of Tamworth Hospital Quarry, and from spot localities in the North Tamworth–Spring Creek area, NE New South Wales. HQ=productive horizons in the Tamworth Hospital Quarry section (Fig. 2). D&P= localities from David & Pittman (1899; cf. Fig. 1 of this report). M&T=other limestone horizons sampled for this report and which proved productive of conodonts (see Fig. 1).

Hospital Quarry (Fig. 3), as well as from blocks excavated during quarrying and left lying on the floor of the quarry, accord with a spectrum of intervals from Eifelian to late Givetian: *costatus* Zone to *kockelianus* Zone; *kockelianus* Zone; *hemiansatus* Zone to Middle *varcus* Subzone; Middle *varcus* Subzone to Late *varcus* Subzone; and *hermanni* Zone. This considerable age-spectrum is consistent with the allochthoneity of the limestones. Comments on specific horizons sampled (see Table 2 for conodont faunas) are:

Conodonts from the top of the large Moore Creek Limestone olistolith at HQ 0, and conodonts (too sheared for determination) from a small olistolith 'near D&P-A' both had high CAI: 5 to 6, equating with >300°C. Conodonts from a limestone clast 'near D&P B' (dominated by belodellids) had remarkably low CAI: 1.5 to 2, equivalent to <140°C. contrast in thermal history of the source rocks for the clast at these three localities.

Belodellids were the main conodont group represented in 'M&T 1' but among them were two polygnathids, *Polygnathus* sp. A and the anterior portion of another form of *Polygnathus* with steep anterior margins of the platform resembling *P. parawebbi*. The latter ranges in age from *australis* Zone to Late *varcus* Zone (Mawson & Talent 1989). Although several limestone conglomerate horizons in the vicinity of 'D&P 8' failed to produce conodonts, one of the samples produced radiolarians tentatively identified as *Trilonche elegans* Hinde 1899.

No age-constraining conodonts were recovered from 'M&T 2' other than simple cones, although the fauna contained a large number and variety of well preserved ostracods. Several elements from a *Prioniodina* apparatus were the only conodonts from 'M&T 3'. Although similar to the Middle Devonian *P. tortoides* Sparling 1981, the exact age of the species of *Prioniodina* from the Tamworth area is uncertain.

All samples from along the section line at the Tamworth Hospital Quarry (Table 1) appear to be from allochthonous clasts. Conodonts from HQ 4, 5, 6 and 7 give ages from *kockelianus* Zone to Early *varcus* Subzone, and are therefore consistent with being clasts derived from Moore Creek Limestone. Samples HQ 1 [loose] and HQ 2A are younger in age, Late *hermanni* Zone. Horizons HQ 1, 2 and 3A failed to produce age-constraining conodonts.

Interestingly, the sharp contrast in CAI values between the Moore Creek Limestone occurrences (5 to 6) and younger horizons in the Yarrimie and Baldwin Formations (1.5 to 2), indicative of a rapid decrease in regional heat flux, occurred contemporaneously with a similar swift decrease in heat flux in the Burdekin Basin of NE Queensland (Talent & Mawson 1994) 1400 km away. This we associate with near cessation of, or a profound decrease in the Tabberabberan tectonism.

2. Age of uppermost Yarrimie Formation

Palmatolepis hassi Müller & Müller, *Ancyrodella curvata* Branson & Mehl and *Ancyrognathus* sp. have been reported by McMinn (1982) from a locality high in the Yarrimie Formation at Yarramanbully. McMinn's materials could not be located, but we have obtained *P. hassi* from essentially the same locality at 927_0920_5 on 1:25 000 topographic map 9036-II-N, Klori (Mawson & Talent, in prep.). The association is indicative of the later half of the Frasnian, specifically the Late *hassi* to *linguiformis* zones (cf. Sandberg & Ziegler 1990), ie. in terms of the former zonal scheme an interval extending from late in the Zone of *Ancyrognathus triangularis* to somewhere in the Uppermost *gigas* Zone, or about zones 6–13 in terms of Klapper's (1989) system based on sections in the Montagne Noire of southern France. Because there is at least 250 m of Yarrimie Formation between this locality and the faulted boundary with the Baldwin Formation. it is conceivably older than David & Pittman's locality D and possibly older even than their locality 8, but this is speculative.

We suggest accordingly that the best approximation of age for the radiolarian fauna from horizon D is not older than late Frasnian. An inevitable corollary from the above is that accumulation of the uppermost Yarrimie Formation of the Tamworth–Yarramanbully area was coeval with accumulation of the Mostyn Vale Formation (Wright et al. 1990; Winchester-Seeto & Paris 1995) of the Keepit area, *c.* 50 km NW of Tamworth.

3. Age of the Baldwin Formation

As noted earlier, David & Pittman's (1899) stratigraphically highest limestone, very low in the Baldwin Formation at their locality 10, failed to produce conodonts, but autochthonous limestones in the Baldwin Formation at Yarramanbully (Marshall 1968), outside the area mapped for this report and, it is stressed, much higher in the formation at 898_5916_5 on 1:25 000 topographic map 9036-II-N, Klori, produced conodonts including *Palmatolepis glabra glabra* Ulrich & Bassler. Our collections from this locality (Mawson & Talent, in prep.) include *Icriodus chojnicensis* Matya. McMinn (1977) reported a similar fauna from the Baldwin Formation E of Yarramanbully and E of the Namoi Fault at 951_0919_5 on the same topographic sheet. In terms of presently known ranges of conodonts, the age indicated is somewhere in the interval Late *rhomboidea* Zone to Early *marginifera* Zone. These limestone intervals may well be representative of the widespread Early *marginifera* Zone transgression in eastern Australia (Talent 1989; Mawson & Talent 1997).

4. *Devonian conodonts from cherts in the Tamworth Belt and adjoining regions*

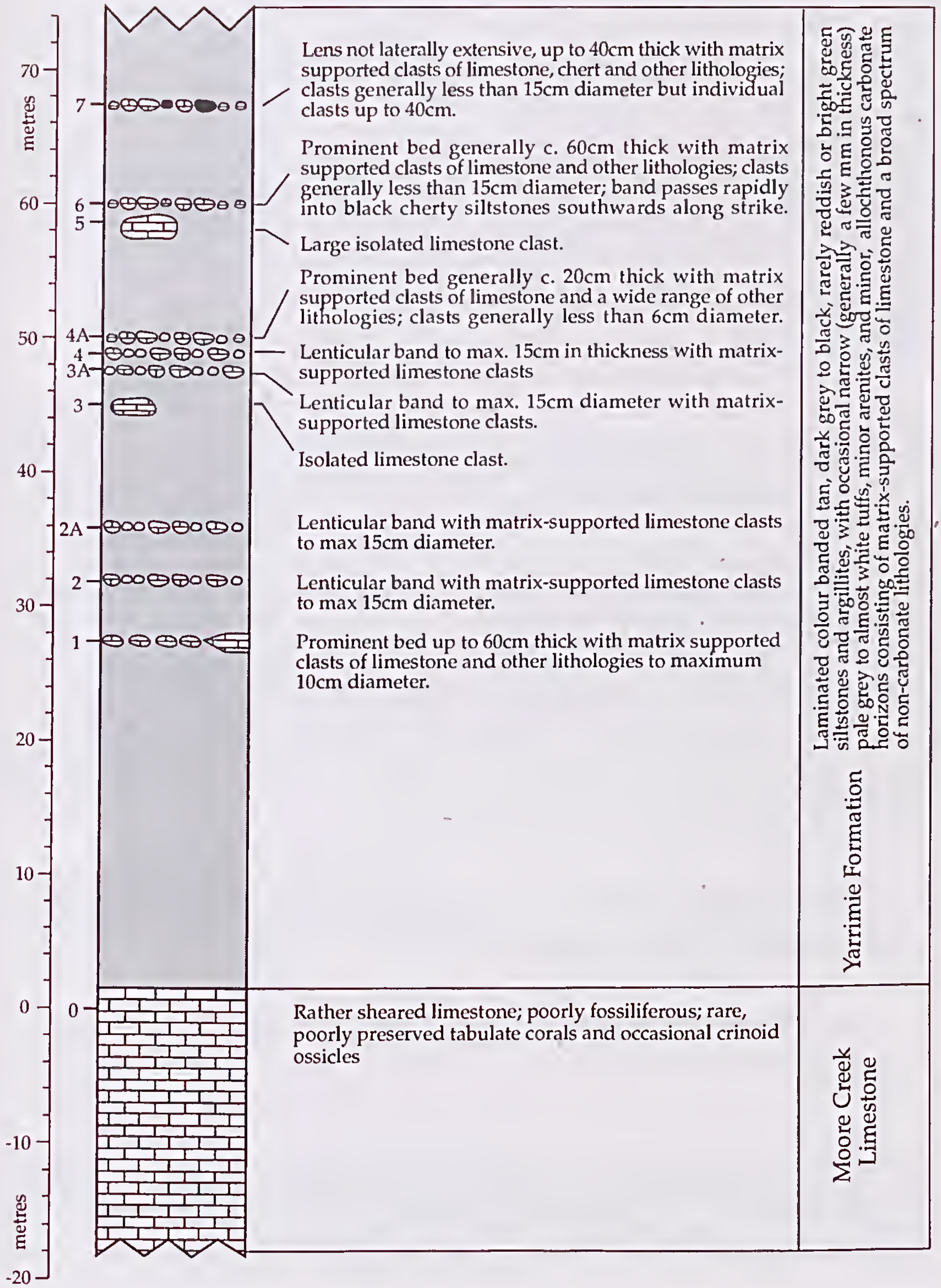
(i) Late Devonian conodonts, obtained as a by-product of hydrofluoric acid leaching in quest of radiolarians, have been reported but not illustrated by Naka et al. (1988) from low in the Baldwin Formation but possibly from high in the Yarrimie Formation (cf. Ishiga & Leitch 1988: fig. 3) from the Tamworth Belt SE of the area considered here. They reported *Polygnathus styriacus*, characteristic of the Famennian Early *postera* to Early *expansa* zones from their samples 2-3-4 and 2-3-5 from an outcrop on the left bank of the Peel River opposite the junction of Burrows Creek, 3 km NNE of Nundle. If this determination is correct, it indicates major diachronism of at least 4 conodont zones (and possibly more) for the Yarrimie–Baldwin boundary between North Tamworth and Nundle: at least Middle *marginifera* Zone to Early *postera* or Early *expansa* zones. This possibility of diachronism needs clarification.

(ii) A latest Silurian/Early Devonian (Pridoli–Pragian) fauna has been documented by Ishiga, Leitch et al. (1988) and Ishiga, Leitch & Watanabe (1988) from the Woolomin Formation in the Macdonald Block at their locality WA-50 approximately 5 km NNW of Dungowan at grid reference 179494 on 1:25 000 topographic sheet 9135-4-S Dungowan. The conodonts indicate that this horizon aligns stratigraphically to somewhere within the Glencairn Limestone of the Willow Tree Creek area, 10 km ENE of Attunga (Leitch et al., manuscript).

(iii) A conodont fauna from the western margin of the Hastings Block obtained by Ishiga & Leitch (1988a) from siltstone at their locality 39-i at Yarras Post Office includes several conodont species. Their fig. 1, identified as *Polygnathus asymmetricus*, is a specimen of *Palmatolepis rhomboidea* Sannemann, a species that may occur from Early *rhomboidea* Zone to Early *marginifera* Zone. Their fig. 2, identified as *Polygnathus asymmetricus*, is a *Palmatolepis* cf. *rhomboidea*. It has the same shagreen ornament and the anterior blade is high, but the orientation of the photograph does not allow positive identification. Their figs 3 and 4, identified as *Polygnathus asymmetricus* Bischoff & Ziegler, are *Polygnathus* sp. indet. The basal pit appears to be symmetrical unlike the basal pit of *Mesotaxis asymmetricus* (Bischoff & Ziegler). Their figs 5 and 6, identified as *Polygnathus* spp., are *Polygnathus communis communis* Branson & Mehl 1934. This species is known to extend through most of the Famennian, commencing in the Middle *crepida* Zone; it extends to the *anchoralis/latus* Zone in the Tournaisian. Their fig. 7 was identified as *Polygnathus* sp. indet.; we accept this identification. Their fig. 8 was referred to *Kockelella* sp., a genus restricted to the Silurian. Its identification is problematic, but it resembles *Ancyrodella*, a genus not known from horizons younger than *triangularis* Zone. If it is indeed *Ancyrodella* it is likely to be a reworked specimen. Their fig. 11 was identified as *Panderodus* sp.; we accept this identification. There were 5 unnamed elements: fig. 9, a Pb element, fig. 12, possibly an M element, figs 10 and 13, Sb elements, and fig. 14 an M element. Based primarily on the co-occurrence of *Palmatolepis rhomboidea* and *Polygnathus communis communis*, the age is inferred to be *rhomboidea* Zone or Early *marginifera* Zone. It therefore equates approximately chronologically with the limestones in the Baldwin Formation of the Yarramanbully area discussed earlier.

(iv) Nondescript mid-Palaeozoic conodonts have been reported but not documented from cherts of the Port Macquarie Block (Ishiga et al. 1988: 56).

Fig. 3. Stratitgraphic column for measured and sampled section across the Tamworth Hospital Quarry showing horizons sampled in quest of conodonts (cf. Table 1). Note that all horizons proved allochthonous; horizon 0 was 60 cm below the top of the Moore Creek Limestone olistolith; horizon 4A proved barren.


metres
70
60
50
40
30
20
10
0
-10
-20
metres
7
6
5
4A
4
3A
3
2A
2
1
0
Lens not laterally extensive, up to 40cm thick with matrix supported clasts of limestone, chert and other lithologies; clasts generally less than 15cm diameter but individual clasts up to 40cm.
Prominent bed generally c. 60cm thick with matrix supported clasts of limestone and other lithologies; clasts generally less than 15cm diameter; band passes rapidly into black cherty siltstones southwards along strike.
Large isolated limestone clast.
Prominent bed generally c. 20cm thick with matrix supported clasts of limestone and a wide range of other lithologies; clasts generally less than 6cm diameter.
Lenticular band to max. 15cm in thickness with matrix-supported limestone clasts
Lenticular band to max. 15cm diameter with matrix-supported limestone clasts.
Isolated limestone clast.
Lenticular band with matrix-supported limestone clasts to max 15cm diameter.
Lenticular band with matrix-supported limestone clasts to max 15cm diameter.
Prominent bed up to 60cm thick with matrix supported clasts of limestone and other lithologies to maximum 10cm diameter.
Rather sheared limestone; poorly fossiliferous; rare, poorly preserved tabulate corals and occasional crinoid ossicles
Laminated colour banded tan, dark grey to black, rarely reddish or bright green siltstones and argillites, with occasional narrow (generally a few mm in thickness) pale grey to almost white tuffs, minor arenites, and minor, allochthonous carbonate horizons consisting of matrix-supported clasts of limestone and a broad spectrum of non-carbonate lithologies.
Yarrimie Formation
Moore Creek Limestone

5. *Conclusions*

David & Pittman's limestone horizons are inferred to have been of various ages from early Emsian to late Frasnian, with the youngest horizon (their locality 10) being conceivably as young as the early Famennian–mid Famennian boundary (Late *rhomboidea* Zone to Early *marginifera* Zone). A broader spectrum of mid-Palaeozoic ages (Pridoli to late Famennian) is indicated by conodonts occurring in association with radiolarians in cherts and siltstones from elsewhere in the region. A summary of the alignments of North Tamworth limestone horizons in relation to the regional stratigraphic pattern and relevant chronologic date is given in Table 2.

NOTES ON CONODONT TAXA

For nomenclature of localities for conodonts in the North Tamworth–Spring Creek area see the map (Fig. 1), stratigraphic column (Fig. 3) and distribution chart (Table 1). The faunas include several chronologically compelling forms that, in autochthonous contexts, would warrant extended discussion. Because of allochthoneity of all limestone horizons sampled, comment is minimal. Abbreviations: AMF=Australian Museum; D&P= sample localities indicated by David & Pittman (1899) on their section line (these are shown within circles in Figs 1 and 2); HQ=Hospital Quarry section; M&T=spot localities located away from David & Pittman's section, and away from the Hospital Quarry section (these are shown without circles in Fig. 1).

Order **CONODONTOPHORIDA** Eichenberg, 1930

Family **Belodellidae** Khodalevich & Tschernich, 1973

Genus *Belodella* Ethington, 1959

Type species. *Belodus devonicus* Stauffer, 1940.

Discussion. Two multi-element interpretations for *Belodella* are presently in use. Klapper & Barrick (1983) distinguish M, Sa, Sb, Sc and Sd elements. Jeppsson's (1989) 'f' element equates with the falciform M element of Klapper & Barrick, additional 'u' and 'a' elements are short and robust with denticulate posterior margins and 'd' elements form a symmetry-transition series thus equating with the S series proposed by Klapper & Barrick (1983). Terminology of Klapper & Barrick (1983) is used herein as the faunas are not sufficiently large to unequivocally identify the elements suggested by Jeppsson (1989).

Belodella resima (Philip, 1965)

Fig. 5M, O, P

Discussion. See Mawson, Talent & Furey-Greig (1995: 424–427) for synonymy. Following Klapper & Barrick (1983) and Stauffer (1940), S elements of *B. resima* may be differentiated from those of *B. devonica* by the absence of longitudinal costae.

Specimens of *Belodella resima* originally described from Tyers, Victoria (Philip 1965), were from horizons dated as *sulcatus* and *kindlei* zones (Mawson & Talent 1994b). Elsewhere in Australia, elements of *B. resima* have been reported and/ or illustrated from the Buchan area, Victoria [*dehiscens* to *serotinus* zones] (Philip 1966b; Mawson 1987b), the Broken River area, N Queensland [*pesavis* Zone to Late *varcus* Subzone] (Telford 1975; Mawson 1987a; Mawson & Talent 1989; Sloan et al. 1995) and Attunga, NSW [*patulus* to Late *varcus* zones] (Mawson & Talent 1994a).

Genus *Dvorakia* Klapper & Barrick, 1983

Type species. *Dvorakia chattertoni* Klapper & Barrick, 1983.

Dvorakia sp.

Fig. 5N

Discussion. As the element illustrated has a

Table 2. Suggested stratigraphic allocation of David & Pittman's (1899) and other limestone horizons in the North Tamworth area in the context of stratigraphic and biochronologic information from the Attunga–Tamworth–Nundle portion of the Tamworth Belt. Not included is the Sulcor Limestone (late Emsian), outcropping in the Sulcor–Yarramanbully area, 4–10 km N of Attunga (for location see inset, Fig. 1); it is inferred (Mawson & Talent, in prep.) to have been a major source of the limestone clasts in the Silver Gully Formation. D&P=David & Pittman (1899). U of S=University of Sydney. M&T=Mawson & Talent, this report.

Baldwin Formation	**D&P C** (not re-located) **D&P 10** limestone clasts (perhaps Moore Ck Limestone Member; barren of conodonts)
Yarrimie Formation	**D&P 9** (barren of conodonts) and D (not re-located). These horizons may be approximate correlates of McMinn's (1982) locality at Yarramanbully which produced late Frasnian *hassi* Zone conodonts **D&P 8** - several conglomeratic limestone horizons (sparse radiolarians), equating approximately with lithologically similar conglomeratic limestone horizons in the Dave's Hill and Bald Hill areas; = **D&P E, F & G**, and **M&T 5. U of S 267** **D&P 3**, equating approximately with **HQ 6** **D&P B**, equating approximately with **HQ 2 & 2A**, and with **M&T 4** **M&T 3** (clast of Moore Creek Limestone very low in Yarrimie Formation Lowest Yarrimie horizons are Early (perhaps not earliest part of the subzone) and Late *varcus* Subzones at Attunga (Mawson & Talent 1994)
Moore Creek Limestone	**M&T 1 & 2** (olistoliths in North Tamworth area); *costatus* and *australis* Zones are represented in the interval transitional from below into the Moore Creek Limestone (Mawson & Talent 1994), massive limestones at Attunga and Yarramanbully extending the age-span through the *kockelianus* Zone to the *hemiansatus* Zone and perhaps into the Early *varcus* Subzone (Mawson & Talent, 1994 & unpub. data).
Unnamed Unit	Not clearly differentiated on David & Pittman's (1899) North Tamworth-Seven Mile Creek traverse, but well-defined in the Yarramanbully and Sulcor areas as clastic and subordinate carbonate interval between Sulcor and Moore Creek Limestones. Referred to as "Lower Yarrimie Formation" by Mawson & Talent (1994) and shown to include *patulus* and *partitus* zones (i.e. straddling the Emsian-Eifelian boundary) at Attunga and be transitional to the Moore Creek Limestone. Laterally equivalent (at least in part) with Silver Gully Formation
Folly Spilite	Well expressed in areas south of Tamworth (e.g. Allen & Leitch 1992) but not identified on David & Pittman's (1899) North Tamworth-Seven Mile Creek traverse; inferred to be late *patulus* Zone or early Eifelian (see text)
Silver Gully Formation	Not clearly differentiated on David & Pittman's (1899) North Tamworth-Seven Mile Creek traverse, but demonstrated to be late *serotinus* - *patulus* Zone at Loomberah Heights (Mawson et al. 1995); Bog Hole Formation includes the same interval (Mawson et al 1995 & unpub. data)
Wogarda Argillite	Not clearly differentiated on the eastern part of David & Pittman's (1899) North Tamworth-Seven Mile Creek traverse
Northcotte Formation	Not clearly differentiated on the eastern part of David & Pittman's (1899) North Tamworth-Seven Mile Creek traverse
Drik Drik Formation	**D&P H-T** - suggested to possibly align with lithologically similar(matrix-supported limestone cobble horizons) in the metamorphic aureole associated with the Moonbi Adamellite west of Seven Mile Creek (cf. Fig. 2), and with generally not strongly metamorphosed developments in the Nemingha-Nundle area inferred (Furey-Greig 1995) to be *dehiscens* Zone; includes interstratified Copes Creek Andesite (Morgan 1997)

slightly asymmetrical, round to triangular cross section, it is designated an Sb element. It closely resembles a specimen illustrated by Klapper & Barrick (1983: fig. 8J) from Salisbury, Howard County, Iowa, from the Middle *varcus* Subzone.

Family **Acanthodontidae** Lindström, 1970

Genus ***Drepanodus*** Pander, 1859

Type species. Drepanodus arcuatus Miller, 1889.

Drepanodus sp.

Fig. 5C

Discussion. Although species of *Drepanodus* are generally taken to be confined to the Ordovician (Sweet 1988), several acostate, long, generally robust, slightly reclined coniform elements occurring in Devonian faunas have been referred to this genus (eg. Philip 1966b; Telford 1975).

Genus ***Panderodus*** Ethington, 1959

Type species. Paltodus unicostatus Branson & Mehl, 1933.

Panderodus unicostatus (Branson & Mehl, 1933)

Fig. 5J

Discussion. See Simpson & Talent (1995: 118–119) for synonymy. Various reconstructions of this species are summarised in Smith et al. (1987), for example those of Bergstrom & Sweet (1966), Cooper (1975) and Barrick (1977).

Genus **Neopanderodus** Ziegler & Lindström, 1971

Type species. Neopanderodus perlineatus Ziegler & Lindström, 1971.

Neopanderodus aequabilis Telford, 1975

Fig. 5K

Discussion. See Mawson et al. (1995: 428) for synonymy. Mawson et al. (1995: 428) suggested that the multielement reconstruction of the *Neopanderodus* may be analogous to that of *Panderodus*. A slender element, possibly an Sc element (pl. 2, fig. 19), has a groove on the inner lateral face running two-thirds the length of the cone, with longitudinal, parallel striae covering the area from the groove to the outer lateral margin, and oblique striae covering the area from the inner margin to the groove.

Neopanderodus sp.

Fig. 5L

Discussion. One neopanderodid specimen with relatively coarse striations developed from the tip of the cone to its base has not been assigned to *Neopanderodus aequabilis* because of the nature of the striations and lack of a lateral groove on the cone.

Family **ICRIODONTIDAE** Müller & Müller, 1957

Genus ***Icriodus*** Branson & Mehl, 1938

Type species. Icriodus expansus Branson & Mehl, 1938.

Icriodus struvei Weddige, 1977

Fig. 5A, B

Discussion. See Mawson (1987a: 258) for synonymy. This narrow form of *I. struvei* is somewhat similar to specimens of *I. regularicrescens*, for example, those illustrated by Weddige (1977: pl. 2, figs 31–32). The latter, however, can be distinguished from *I. struvei* in having a platform

Fig. 4. A–D, *Polygnathus linguiformis linguiformis* Hinde 1897. A, upper view of AMF99074, ×35, HQ 5. B, upper view of AMF990975, ×45, HQ 6. C, D, lateral and upper views respectively of AMF990976, ×60, HQ 7 (loose). E, F, *Polygnathus aequalis* Klapper & Lane 1985. Lower and upper views respectively of AMF990978, ×35, HQ 2A. G, H, *Polygnathus aequalis* Klapper & Lane 1985. Lower and upper views respectively of AMF990979, ×60, HQ 1 (loose). I, *Polygnathus cooperi cooperi* Klapper, 1971. Upper view of AMF990977, HQ 5. J–M, *Polygnathus cristatus* Hinde 1879. J, enlargement showing asymmetry of basal pit of AMF99083, ×300, HQ 2A. K–M, lower, lateral and upper views respectively of AMF99083, ×60, HQ 2A.


A
B
E
F
C
D
G
H
I
J
K
L
M

that is narrower posteriorly. In Australia, *I. struvei* occurs in horizons ranging in age from *costatus* Zone to *hemiansatus* Zone (Mawson & Talent 1989).

Family **Prioniodontidiae** Bassler, 1925

Genus ***Prioniodina*** Bassler, 1925

Type species. Prioniodina subcurvata Bassler, 1925.

Prioniodina sp. A

Fig. 5F–I

Discussion. Several elements with similar denticulation and occurring in a single fauna (sample M&T-1 from the Moore Creek Limestone), have been assigned to *Prioniodina* sp. A. In lateral view, the slightly damaged prioniodellan (Pa) element is weakly arched in lateral view and has tall, closely packed but discrete denticles, round in cross section and tilted towards the posterior. The basal cavity is expanded in the anterior third of the unit and extends as a narrow groove to the posterior. The prioniodinan (?Pb) element is characteristically twisted with the basal cavity inverted anteriorly. It is far less angulate than the prioniodinan element of *Pri. subcurvata* as illustrated by Huddle (1968). The ?Sb element (longidensiform element of Sparling 1981) and the Sc element (ligonodinan element) have denticles that are similarly rounded to those of the P elements, but they are not as closely packed.

Family **Spathognathodontidae** Hass, 1959

Genus ***Tortodus*** Weddige, 1977

Type species. Tortodus kockelianus (Bischoff & Ziegler, 1957).

Tortodus kockelianus kockelianus
(Bischoff & Ziegler, 1957)

Figs 4L, M; 3D, E

Discussion. See Klapper & Johnson (1980: 455) for basic synonymy. The smooth, platform-like bulges on either side of the central row of denticles distinguishes *T. k. kockelianus* from *T. k. australis.* Despite damage to both specimens recovered from horizon HQ-0, they are readily identified as specimens of *T. k. kockelianus* by the characteristic platform bulges, the inward twist of the posterior part of the platform and the accompanying inclination of the denticles. The incoming of *T. k. kockelianus* marks the beginning of the *kockelianus* Zone *sensu stricto*; ie. it extends into the post-*kockelianus*/pre-*hemiansatus* interval that remained after excision of the *hemiansatus* Zone.

Family **Polygnathidae** Bassler, 1925

Genus ***Polygnathus*** Hinde, 1879

Type species. Polygnathus dubius Hinde, 1979.

Polygnathus aequalis Klapper & Lane, 1985

Fig. 3G, H

Discussion. See Klapper & Lane (1985: 930) and Bultynck & Martin (1995: 19) for synonymy of the species. A right curved specimen of *P. aequalis* was recovered from sample HQ 1 (loose) in the Hospital Quarry. It is a right-hand form having anterior margins of equal height and ridged ornamentation and platform dimensions very similar to those of the specimen figured by Klapper & Lane (1985: fig. 16.10) and the specimen figured by Bultynck & Martin (1995: pl. 8, fig. 8).

Fig. 5. A–E, *Polygnathus xylus xylus* Stauffer 1940. A, B, upper and lower views respectively of AMF990984, ×90, HQ 2A. C, upper view of AMF990985, ×30, HQ 4. D, E, upper and lateral views respectively of AMF990986, ×60 and ×55 respectively, HQ 1 (loose). F, G, *Polygnathus hemiansatus* Bultynck 1987. Lateral and upper views respectively of AMF99082, ×45, HQ 4. H, I, *Polygnathus* cf. *ovatinodosus* Ziegler & Klapper 1976. Upper and lower views respectively of AMF990988, ×35, HQ 2A. J, K, *Polygnathus* sp. A. Lateral and upper views of AMF99091, ×45, M&T 1. L, M, *Tortodus kockelianus kockelianus* (Bischoff & Ziegler 1957). Lower and upper views respectively of AMF990980, ×60, HQ 0. N, O, *Polygnathus pennatus* Hinde 1879. Lateral and upper views respectively of AMF990990, ×60, HQ 1 (loose).


A
B
C
D
E
F
H
I
J
K
G
L
M
N
O

Polygnathus cooperi cooperi Klapper, 1971

Fig. 3I

Discussion. See Mawson et al. (1995: 431) for synonymy. One polygnathid is referred to *P. c. cooperi* because of its shallow depressions paralleling the carina, the gradual rounding of the posterior platform that forms a tongue, the short, discrete ridges on the margins of the platform and the ridges on the tongue that are partly interrupted as a continuation of the carina. It is generally agreed that the youngest specimens of *P. c. cooperi* occur in the *costatus* Zone. Bultynck & Hollard (1980) and Ziegler et al. (1976) recorded this subspecies as occurring in horizons as old as *serotinus* Zone.

Polygnathus cristatus Hinde, 1879

Fig. 3J–M

Discussion. See Klapper & Johnson (1980: 452) for synonymy. The leaf-like, nodose, arched platform and the basal pit surrounded by slightly asymmetrical lips that extend as a keel both posteriorly and anteriorly identify this as being a specimen of *P. cristatus*. The occurrence of this species in the HQ 2A fauna indicates an age no older than the upper half of the *hermanni* Zone (late Givetian), but possibly as young as the middle *asymmetricus* Zone (early Frasnian) (Higgins & Austin 1985; Sweet 1988; Barskov et al. 1991).

Polygnathus hemiansatus Bultynck, 1987

Fig. 4F, G

Discussion. See Bultynck (1987: 161) for basic synonymy. This species is recognised by having an almost straight inner platform margin contrasting with the outer platform margin with its pronounced constriction along the anterior margin. Bultynck et al. (1993) proposed that the definition of the Eifelian–Givetian boundary should be based on the entry of the species *P. hemiansatus* as defined by them; this has now been ratified by the International Union of Geological Sciences.

Polygnathus linguiformis linguiformis Hinde, 1879

Fig. 3A–D

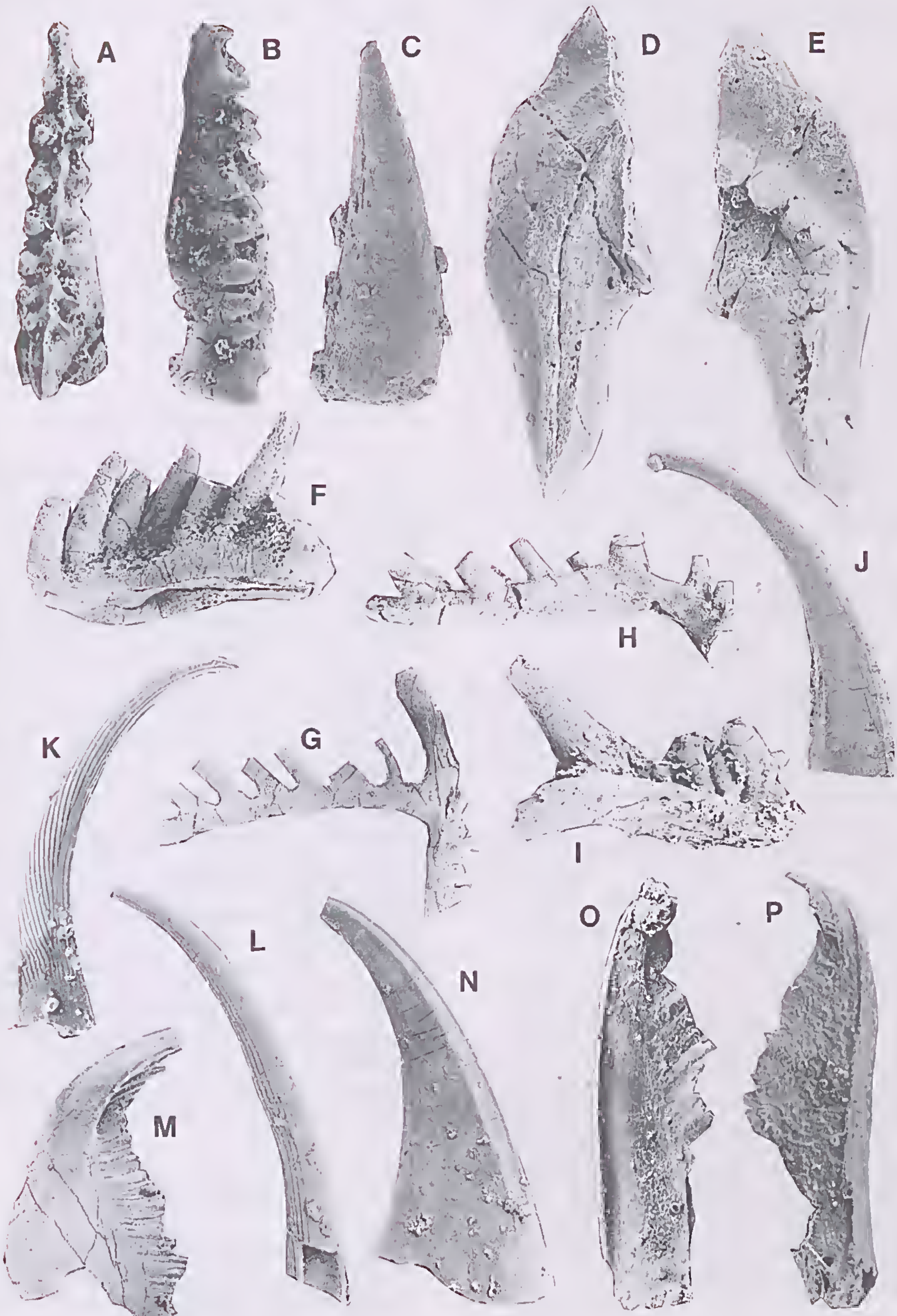
Discussion. See Mawson et al. (1995: 432) for synonymy. Also known in the literature as *Polygnathus linguiformis* gamma morph (eg. Bultynck 1970), this polygnathid is a long-ranging form. In Australia it is known from latest *serotinus* Zone through to the Middle *varcus* Subzone (Mawson & Talent 1989), but it could be expected from still younger horizons. Higgins & Austin (1985) have it extending from the *costatus* Zone through to the Lower *asymmetricus* Zone; Barskov et al. (1991) show the range to be *costatus* Zone to *asymmetricus* Zone. Klapper (in Ziegler et al. 1977) gives the range as from early Middle Devonian to early Upper Devonian (*asymmetricus* Zone).

Polygnathus linguiformis klapperi Clausen et al., 1979

Fig. 3E, F

Discussion. See Olivieri (1985: 303) for synonymy. Originally recognised as *P. linguiformis* epsilon morph (eg. Klapper in Ziegler 1977), Clausen et al. (1979) raised this form to subspecies level. Barskov et al. (1991) show this subspecies ranging from horizons dated as upper *ensensis* (=*hemiansatus*) Zone to *hermanni*–

Fig. 6. A, B, *Icriodus struvei* Weddige 1977. Upper and lateral views respectively of AMF990989, ×50, HQ 7. C, *Drepanodus* sp. Lateral view of AMF99087, ×60, HQ 2A. D, E, *Tortodus kockelianus kockelianus* (Bischoff & Ziegler 1957). Lower and upper views respectively of AMF990981, ×60, HQ 0. F–I, *Prioniodina* sp. A. F, lateral view of Pa element, ×45, AMF99092, M&T 3. G, lateral view of Sc element, AMF99095, ×25, M&T 3. H, lateral view of ?Sb element, AMF99094, ×35, M&T 3. I, lateral view of ?Pb element, AMF99093, ×35, M&T 3. J, *Panderodus unicostatus* (Branson & Mehl, 1933a). Lateral view of ?tortiform element, AMF99100, ×60, HQ 2A. K, *Neopanderodus aequabilis* Telford 1975. Lateral view of AMF99096, ×60, HQ 5. L, *Neopanderodus* sp. Lateral view of AMF99097, ×90, HQ 5. M, O, P, *Belodella resima* (Philip 1965). M, lateral view of Sc element, AMF99098, ×75, HQ 2A. O, lateral view of Sa element, AMF99099, ×60, HQ 1. P, lateral view of Sa element, AMF99101, ×60, HQ 2. N, *Dvorakia* sp. Lateral view of Sb element, AMF99102, ×90, HQ 1 (loose).


A
B
C
D
E
F
J
H
K
G
I
O
P
L
N
M

cristatus Zone. Klapper & Johnson (1980) indicate this form to be present in the Lowermost *asymmetricus* Zone in Indiana.

Polygnathus cf. **ovatinodosus** Ziegler & Klapper, 1976

Fig. 4H, I

Discussion. See Klapper & Johnson (1980: 453) for basic synonymy of *P. ovatinodosus*. The specimen from HQ 2A is compared to *P. ovatinodosus* as there is a suggestion of the outer anterior trough bowing outwards, a feature not usual in *P. ovatinodosus*. It has, however, a relatively flat platform, the typical nodose ornamentation on the platform, and a short rostrum; the platform and blade are of equal length and the pit is located in the rostral area. These features identify *P. ovatinodosus*. Barskov et al. (1991) and Klapper & Johnson (1980) gave the range of this species as Middle *varcus* Subzone to Lowermost *asymmetricus* Zone.

Polygnathus pennatus Hinde, 1879

Fig. 4N, O

Discussion. See Norris et al. (1992: 78–79) for synonymy. This specimen has a lanceolate platform, a high carina that reaches the posterior extremity of the platform, and distinct marginal ridges, typical of *P. pennatus*. Barskov et al. (1991) show this species to occur only in horizons of Lowermost *symmetricus* to Middle *asymmetricus* age. Klapper (in Ziegler 1973) noted the occurrence of this species in the upper part of the *hermanni–cristatus* Zone in the Rhenish Slate Mountains (Ziegler 1966).

Polygnathus xylus xylus Stauffer, 1940

Fig. 4A–E

Discussion. See Sparling (1995: 1137) for synonymy. *P. xylus xylus* differs from *P. x. ensensis* in having fewer serrations developed along the anterior part of the platform margins slightly posterior of the geniculation points. In some specimens of *P. x. xylus*, a slight serration may be seen, eg. Fig. 4E. The latter specimen also lacks the strong downward arching of the platform posterior to the serrations, another feature of characteristic of *P. x. ensensis*. *P. x. xylus* is known to occur in faunas of varcus to Lower *asymmetricus* age (Barskov et al. 1991; Sweet 1988).

Polygnathus sp. A.

Fig. 4J, K

Discussion. A single Pa element is recorded from locality M&T-1. The narrow, slightly curved platform is highly arched for its size and is ornamented with nodes or short ridges for the length of the platform. The blade is high and is equal in length to the platform. The platform is a little too asymmetrical for it to be a small specimen of *P. decorosus* Stauffer.

ACKNOWLEDGEMENTS

We pay tribute to the pioneer contributions, almost a century ago, by T. W. E. David, E. F. Pittman, G. J. Hinde, R. Etheridge and W. N. Benson in the Tamworth and adjacent areas. In the present investigation, Pang was primarily responsible for geological mapping; Mawson and Talent are responsible for the sampling and opinions regarding conodont zonal attribution of the radiolarian faunas. A supportive group of Macquarie University colleagues assisted with acid-leaching, sodium polytungstate separations, SEM photography, drafting, and preparation of plates. Colleagues at the University of New England and the University of Sydney endeavoured, without success, to locate the conodont faunas from Yarramanbully identified by Marshall (1968) and McMinn (1977). Evan Leitch, Terry Furey-Greig and Tim Sharp of the University of Technology Sydney provided samples of numerous limestone intervals within the Baldwin Formation N of Tamworth. Our manuscript has benefited from helpful comments from Evan Leitch and Ian Metcalfe. The project was supported by a grant from the Australian Research Committee. It is a contribution to IGCP Project 421: *North Gondwana mid-Palaeozoic bioevent/biogeography patterns in relation to crustal dynamics.*

REFERENCES

Aitchison, J. C. & Flood, P. G., 1992. Late Devonian accretion of the Gamilaroi Terrane to Gondwana: provenance linkage provided by quartzite clasts in the overlap sequence. *Australian Journal of Earth Sciences* 39: 539–544.

AITCHISON, J. C. & FLOOD, P. G., 1995. Gamilaroi Terrane: a Devonian intra-oceanic island-arc assemblage, NSW, Australia. In *Volcanism associated with Extension at Consuming Plate Margins*, J. L. Smellie, ed., Geological Society of London, 155–168.

AITCHISON, J. C., FLOOD, P. G. & SPILLER, F. C. P., 1992. Tectonic setting and palaeoenvironment of terranes in the southern New England Orogen, eastern Australia as constrained by radiolarian biostratigraphy. *Palaeogeography, Palaeoclimatology, Palaeoecology* 94: 31–54.

AITCHISON, J. C. & STRATFORD, J. M. C., 1997. Middle Devonian (Givetian) Radiolaria from eastern New South Wales, Australia: a reassessment of the Hinde (1899) fauna. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen* 203: 369–390.

AITCHISON, J. C., STRATFORD, J. M. C. & SPILLER, F. C. P., in press. A Lower and Middle Devonian radiolarian biozonation from the Gamilaroi Terrane, New England Orogen, eastern Australia. *Micropalaeontology*

ALLEN, A. D. & LEITCH, E. C., 1992. The nature and origin of eclogitic blocks in serpentinite from the Tamworth Belt, New England Fold Belt, eastern Australia. *Australian Journal of Earth Sciences* 39: 29–35.

BARRICK, J. E., 1977. Multi-element simple-cone conodonts from the Clarita Formation (Silurian), Arbuckle Mountains, Oklahoma. *Geologica et Palaeontologica* 11: 47–68.

BARRICK, J. E. & KLAPPER, G., 1992. Late Silurian–Early Devonian conodonts from the Hunton Group (Upper Henryhouse, Haragan, and Bois d'Arc formations), south-central Oklahoma. *Oklahoma Geological Survey Bulletin* 145: 19–65.

BARSKOV, I. S., VORONTSOVA, T. N., KONONOVA, L. I. & KUZ'MIN, A. V., 1991. *Opredelitel' konodontov devona i nizhnego karbona*. Moskovskiy gosudarstvennyy universitet, Moskva, 183 pp.

BENSON, W. N., 1915. The geology and petrology of the Great Serpentine Belt of New South Wales. Part V. The geology of the Tamworth district. *Proceedings of the Linnaean Society of New South Wales* 40: 540–624, pls XLIX–LIII.

BENSON, W. N., 1917. The geology and petrology of the Great Serpentine Belt of New South Wales. Appendix to Part VI. The Attunga district. *Proceedings of the Linnaean Society of New South Wales* 42: 693–700.

BENSON, W. N, 1918. The geology and petrology of the Great Serpentine Belt of New South Wales. Appendix to Part VII. The geology of the Loomberah district and a portion of the Goonoo Goonoo Estate. *Proceedings of the Linnaean Society of New South Wales* 43: 320–360, 363–384, pls XXXI–XXXVIII.

BERGSTROM, S. M. & SWEET, W. C., 1966. Conodonts from the Lexington Limestone (Middle Ordovician) of Kentucky and its lateral equivalents in Ohio and Indiana. *Bulletins of American Palaeontology* 50: 271–441.

BROWN, I. A., 1942. The Tamworth Series (Lower and Middle Devonian) near Attunga, NSW. *Journal and Proceedings of the Royal Society of New South Wales* 76: 166–176.

BROWN, I. A., 1944. Stringocephalid Brachiopoda in eastern Australia. *Journal and Proceedings of the Royal Society of New South Wales* 77: 119–129, pls 4–5.

BRÜHL, D. & POHLER, S. M. Y., manuscript. Tabulate corals from the Moore Creek Limestone (Middle Devonian: late Eifelian–early Givetian), Tamworth Belt, New South Wales, Australia.

BULTYNCK, P., 1970. Revision stratigraphique et paléontologique (brachiopodes et conodontes) de la coupe type du Couvinien. *Mémoires de l'Institut géologique de l'Université de Louvain* 26: 1–152.

BULTYNCK, P., 1987. Pelagic and neritic conodont successions from the Givetian pre-Sahara Morocco and the Ardennes. *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre* 57: 149–181.

BULTYNCK, P. & HOLLARD, H., 1980. Distribution comparée de conodontes et goniatites dévoniens des plaines du Dra, du Ma'der et du Tafilalt (Maroc). *Aardkundige Mededelingen* 1: 1–73.

BULTYNCK, P. & MARTIN, F., 1995. Assessment of an old stratotype: the Frasnian/Famennian boundary at Senzeilles, southern Belgium. *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre* 65: 5–34.

BULTYNCK,, P., WALLISER, O. H. & WEDDIGE, K., 1993. Conodont based proposal for the Eifelian–Givetian boundary. *Subcommission on Devonian Stratigraphy Newsletter* 9: 6–8.

CAWOOD, P. A., 1980. *The geological development of the New England Fold Belt in the Woolomin–Nemingha and Wiseman's Arm regions: the evolution of a Palaeozoic forearc terrain.* Unpublished PhD thesis, University of Sydney, 429 pp.

CLAUSEN, C. D, LEUTERITZ, K. & ZEIGLER, W., 1979. Biostratigraphie und Lithofazies der Elsper Mulde. *Geologische Jahrbuch* 51: 3–37.

CHAPPELL, B. W., 1961. The stratigraphy and structural geology of the Manilla–Moore Creek district, NSW. *Journal and Proceedings of the Royal Society of New South Wales* 95: 63–75.

CONAGHAN, P. J., MOUNTJOY, E. W., EDGECOMBE, D. R., TALENT, J. A. & OWEN, D. E., 1976. Nubrigyn algal reefs (Devonian), eastern Australia: allochthonous blocks and mega-breccias. *Journal of the Geological Society of America* 87: 515–530.

COOPER, B. J., 1975. Multi-element conodonts from the Brassfield Limestone (Silurian) of southern Ohio. *Journal of Paleontology* 49: 984–1008.

CROOK, K. A. W., 1961a. Stratigraphy of the Tamworth Group (Lower and Middle Devonian), Tamworth–Nundle district, NSW. *Journal and Proceedings of the Royal Society of New South Wales* 94: 173–188.

Crook, K. A. W., 1961b. Stratigraphy of the Parry Group (Upper Devonian–Lower Carboniferous), Tamworth–Nundle district, NSW. *Journal and Proceedings of the Royal Society of New South Wales* 94: 189–207.

Crook, K. A. W., 1964. Depositional environments and provenance of Devonian and Carboniferous sediments in the Tamworth Trough, NSW. *Journal and Proceedings of the Royal Society of New South Wales* 97: 41–53.

David, T. W. E., 1896. The occurrence of Radiolaria in Palaeozoic rocks in New South Wales. *Proceedings of the Linnaean Society of New South Wales* 21: 553–570, pls XXXVII, XXXVIII.

David, T. W. E. & Pittman, E. F., 1899. On the Palaeozoic radiolarian rocks of New South Wales. *Quarterly Journal of the Geological Society of London* 55: 16–37, pls II–VII.

Dongal, G. M. S., 1995. Early Devonian (Pragian and early Emsian) fauna from the eastern Tamworth Terrane, New South Wales. *Memoirs of the Australasian Association of Palaeontologists* 18: 131–142.

Dun, W. S., 1900. [untitled]. In *New South Wales Department of Mines Annual Report* 1900: 195.

Ellenor, D. W., 1975. Sedimentation of the Lower–Middle Devonian Tamworth Group, northeastern NSW: a synthesis. *Journal of the Geological Society of Australia* 22: 311–325.

Etheridge, R., Jnr, 1899. On the corals of the Tamworth district, chiefly from the Moore Ck and Woolomol limestones. *Records of the Geological Survey of New South Wales* 6: 151–182, pls 16–38.

Furey-Greig, T. M., 1995. The 'Nemingha' and 'Loomberah' limestones (Early Devonian; Emsian) of the Nemingha–Nundle area, northern New South Wales: conodont data and inferred environments. *Courier Forschungsinstitut Senckenberg* 117: 217–233.

Higgins, A. C. & Austin, R. L. (eds), 1985. A statigraphical index of conodonts. 242 pp. Ellis Horwood, Chichester.

Hill, D., 1942. The Devonian rugose corals of the Tamworth district of NSW. *Journal and Proceedings of the Royal Society of New South Wales* 76: 142–164, pls II–IV.

Hinde, G. J., 1899. On the Radiolaria in the Devonian rocks of New South Wales. *Quarterly Journal of the Geological Society of London* 55: 38–64, pls VIII, IX.

Huddle, J. W., 1968. Redescription of Upper Devonian conodont genera and species proposed by Ulrich and Bassler in 1926. *United States Geological Survey Professional Paper* 578: 1–55, 17 pls.

Ishiga, H. & Leitch, E. C., 1988a. Stratigraphy of the western part of the Hastings Block, New England Fold Belt, eastern Australia. *Preliminary Report on the Geology of the New England Fold Belt, Australia* (No. 1): 33–45, pls 1–2. Co-operative Research Group of Japan and Australia, Tokushima University, Tokushima.

Ishiga, H. & Leitch, E. C., 1988b. Age and significance of Late Devonian radiolarians from the Tamworth Belt, southern New England Fold Belt, eastern Australia. *Preliminary Report on the Geology of the New England Fold Belt, Australia* (No. 1): 61–72, pls 1–2. Co-operative Research Group of Japan and Australia, Tokushima University, Tokushima.

Ishiga, H., Leitch, E. C., Watanabe, T., Naka, T. & Iwasaki, M., 1988. Radiolarian and conodont biostratigraphy of siliceous rocks from the New England Fold Belt. *Australian Journal of Earth Sciences* 35: 73–80.

Ishiga, H., Watanabe, T. & Leitch, E. C., 1988. Microfossil biostratigraphy and lithologic association of bedded chert in the Macdonald Block of the New England Fold Belt, eastern Australia. *Preliminary Report on the Geology of the New England Fold Belt, Australia* (No. 1): 47–59, pls 1–3. Co-operative Research Group of Japan and Australia, Tokushima University, Tokushima.

Jeppsson, L., 1989. Latest Silurian conodonts from Klonek, Czechoslovakia. *Geologica et Palaeontologica* 23: 21–37.

Klapper, G., 1989. The Montagne Noire Frasnian (Upper Devonian) conodont succession. In *Devonian of the World, Proceedings of the Second International Symposium on the Devonian System*, N. J. McMillan, A. F. Embry & D. J. Glass, eds, Canadian Society of Petroleum Geologists, Calgary, *Canadian Society of Petroleum Geologists Memoirs* 14(III): 449–468, 4 pls. [Imprint 1988.]

Klapper, G. & Barrick, J. E., 1983. Middle Devonian (Eifelian) conodonts from the Spillville Formation in northern Iowa and southern Minnesota. *Journal of Paleontology* 57: 1212–1243.

Klapper, G. & Johnson, J. G., 1980. Endemism and dispersal of Devonian conodonts. *Journal of Paleontology* 54: 400–455.

Klapper, G. & Lane, H. R., 1985. Upper Devonian (Frasnian) conodonts of the Polygnathus biofacies, N.W.T., Canada. *Journal of Paleontology* 59: 904–951.

Klyza, J. S., 1995. Middle Devonian conodonts from the Moore Creek Limestone Member, east of Attunga, New South Wales. *Association of Australasian Paleontologists Memoir* 18: 122–130.

Leitch, E. C., Cawood, P. A. & Mawson, R., manuscript. Palaeozoic rocks of the Willow Tree Creek district, northeastern NSW: sequence, structure, age, and regional significance.

Mamet, B. & Pohler, S. M. L., manuscript. Algae from Lower/Middle Devonian limestones in the Tamworth Belt of New South Wales, Australia.

Marshall, A. J., 1968. *Stratigraphy of the Yarramanbully area, near Manilla, NSW.* Unpublished BSc(Hons) dissertation, University of New England, Armidale, x+97 pp, 19 pls.

Mawson, R., 1987a. Documentation of conodont assemblages across the Early Devonian–Middle Devonian boundary at Jessey Springs, North Queensland, Australia. *Courier Forschungsinstitut Senckenberg* 92: 251–273.

MAWSON, R., 1987b. Early Devonian conodont faunas from Buchan and Bindi, Victoria, Australia. *Palaeontology* 30: 251–297, pls 31–41.

MAWSON, R. & TALENT, J. A., 1989. Late Emsian–Givetian conodont stratigraphy and biofacies—carbonate slope and offshore shoal to lagoon and nearshore carbonate ramp—Broken River, north Queensland, Australia. *Courier Forschungsinstitut Senckenberg* 117: 205–259.

MAWSON, R. & TALENT, J. A., 1994a. The Tamworth Group (mid-Devonian) at Attunga, New South Wales—conodont data and inferred ages. *Courier Forschungsinstitut Senckenberg* 168: 37–59.

MAWSON, R. & TALENT, J. A., 1994b. Age of an Early Devonian carbonate fan and isolated limestone clasts and megaclasts, east-central Victoria. *Proceedings of the Royal Society of Victoria* 106: 31–70.

MAWSON, R. & TALENT, J. A., 1997. Late Devonian–Early Carboniferous conodonts and the Devonian–Early Carboniferous transgressions and regressions in northeastern Australia. *Geological Society of America Special Paper*, No. 321: 189–233.

MAWSON, R. & TALENT, J. A., 1998. The Devonian of eastern Australia: stratigraphic alignments, stage and series boundaries, and the transgression–regression pattern re-considered. *Courier Forschungsinstitut Senckenberg* (in press).

MAWSON, R. & TALENT, J. A., in prep. Age-implications of Devonian conodonts from Sulcor and Yarramanbully, north-eastern New South Wales.

MAWSON, R., TALENT, J. A., BEAR, V. N C., BENSON, D. S., BROCK, G. A., FARRELL, J. R., HYLAND, K. A., PYEMONT, B. D., SLOAN, T. R., SORENTINO, L., STEWART, M. I., TROTTER, J. A., WILSON, G. A. & SIMPSON, A. G., 1989. Conodont data in relation to resolution of stage and zonal boundaries for the Devonian of Australia. In *Devonian of the World, Proceedings of the Second International Symposium on the Devonian System*, N. J. McMillan, A. F. Embry & D. J. Glass, eds, *Canadian Society of Petroleum Geologists, Calgary, Canadian Society of Petroleum Geologists Memoirs* 14(III): 485–527, 2 pls. [Imprint 1988.]

MAWSON, R., TALENT, J. A. & FUREY-GREIG, T. M., 1995. Coincident conodont faunas (late Emsian) from the Yarrol and Tamworth belts of northern New South Wales and central Queensland. *Courier Forschungsinstitut Senckenberg* 182: 421–445.

MAWSON, R., TALENT, J. A. & LEITCH, E. C., 1996. Ages and relationships of Devonian rocks from the southeastern New England Fold Belt. *Geological Society of Australia Abstracts* 41: 277.

MCMINN, A., 1977. *Sedimentology and stratigraphy of the Tamworth and Baldwin Groups in the Yarramanbully district, western New England Fold Belt.* Unpublished BSc(Hons) dissertation, University of Sydney.

MCMINN, A., 1982. Age and facies distribution of the Yarrimie and Baldwin formations in the Manilla district. In *New England Geology*, P. G. Flood & B. Runnegar, eds, Department of Geology, University of New England, Armidale, 113–120.

METCALFE, I., AITCHISON, J. C. & STRATFORD, J. M. C., 1997. Lower Devonian (Emsian) microfauna from the Gamilaroi Terrane at Glenrock in the southern New England Orogen, New South Wales. *Proceedings of the Linnaean Society of New South Wales* 118: 123–130.

MORGAN, E. J., 1997. Early Devonian subaqueous andesitic volcanism in the New England Fold Belt, eastern Australia. *Australian Journal of Earth Sciences* 44: 227–236.

NAKA, T., KUWAHARA, K., ISHIGA, H. & LEITCH. E. C., 1988. Age and significance of Late Devonian conodonts from the Tamworth Belt, southern New England Fold Belt, eastern Australia. *Preliminary Report on the Geology of the New England Fold Belt, Australia* (No. 1): 73–77. Co-operative Research Group of Japan and Australia, Tokushima University, Tokushima.

NORRIS, A. W., UYENO, T. T., SARTENAER, P. & TELFORD, P. G., 1992. Brachiopod and conodont faunas from the uppermost Williams Island Formation and Lower Long Rapids Formation (Middle and Upper Devonian), Moose River Basin, northern Ontario. *Geological Survey of Canada Bulletin* 434: 133 pp.

OLIVIERI, R., 1985. Middle and Late Devonian conodonts from southwest Sardinia. *Bollettino della Societa Paleontologica Italiana* 23: 269–310, 9 pls.

PANG, D., 1995. Geology of the Spring Creek district, near Tamworth. Unpublished dissertation, University of Technology Sydney, Sydney, 108 pp.

PEDDER, A. E. H., 1967. *Studies in the Devonian tetracoral faunas of Tasmania, Victoria and New South Wales.* Unpublished PhD thesis, University of New England, Armidale.

PEDDER, A. E. H., 1968. The Devonian system of New England, New South Wales, Australia. In *International Symposium on the Devonian System*, D. H. Oswald, ed., Alberta Society of Petroleum Geologists, Calgary, 2: 135–142.

PEDDER, A. E. H., JACKSON, J. H. & ELLENOR, D. W., 1970. An interim account of the Middle Devonian Timor Limestone of north-eastern New South Wales. *Proceedings of the Linnaean Society of New South Wales* 94: 242–272, pls XIV–XXIV.

PHILIP, G. M., 1965. Lower Devonian conodonts from the Tyers area, Gippsland, Victoria. *Papers and Proceedings of the Royal Society of Victoria* 79: 95–115.

PHILIP, G. M., 1966a. Middle Devonian conodonts from the Moore Creek Limestone, northern New South Wales. *Papers and Proceedings of the Royal Society of New South Wales* 110: 151–161, 3 pls.

PHILIP, G. M., 1966b. Lower Devonian conodonts from the Buchan Group, eastern Victoria. *Micropaleontology* 12: 441–460.

PICKETT, J. W., 1969. Middle and Upper Palaeozoic sponges from New South Wales. *Memoirs of the*

Geological Survey of New South Wales. *Palaeontology* 15: 38 pp, 20 pls.

PICKETT, J. W. & POHLER, S., 1993. The Alaskan Devonian sphinctozoan *Hormospongia* (Porifera) in eastern Australia. *Alcheringa* 17: 158.

POHLER, S. M. L., manuscript. Carbonate sedimentology and geological setting of the late Early to Middle Devonian Yarramanbully limestones, Manilla, NSW.

POHLER, S. M. L. & HERBERT, C., 1993. Carbonate sedimentology of the Middle Devonian Wyaralong limestone near Attunga, N.S.W. *Memoirs of the Association of Australasian Palaeontologists* 15: 255–278.

SANDBERG, C. A. & ZIEGLER, W., 1990. The Late Devonian standard conodont zonation. *Courier Forschungsinstitut Senckenberg* 121: 1–115.

SIMPSON, A. J. & TALENT, J. A., 1995. Silurian conodonts from the headwaters of the Indi (upper Murray) and Buchan rivers, southeastern Australia, and their implications. *Courier Forschungsinstitut Senckenberg* 182: 79–215.

SLOAN, T. R., TALENT, J. A., MAWSON, R., SIMPSON, A. J., BROCK, G. A., ENGELBRETSEN, M., JELL, J. S., AUNG, A. K., PFAFFENRITTER, C., TROTTER, J. & WITHNALL, I. W., 1995. Conodont data from Silurian–Middle Devonian carbonate fans, debris flows, allochthonous blocks and adjacent autochthonous platform margins. *Courier Forschungsinstitut Senckenberg* 182: 1–77.

SMITH, M. P., BRIGGS, D. E. & ALDRIDGE, R. J., 1987. A conodont animal from the lower Silurian of Wisconsin, USA, and the apparatus architecture of panderodontid conodonts. In *Palaeobiology of Conodonts*, R. J. Aldridge, ed., Ellis Horwood, Chichester, 91–104.

SPARLING, D. R., 1981. Middle Devonian conodont apparatuses with seven types of elements. *Journal of Paleontology* 55: 295–316.

SPARLING, D. R., 1995. Conodonts fürom the Middle Devonian Plum Brook shale of north-central Ohio. *Journal of Paleontology* 69: 1123–1139.

STAUFFER, C. R., 1940. Conodonts from the Devonian and associated clays of Minnesota. *Journal of Paleontology* 14: 417–435.

STRATFORD, J. M. C. & AITCHISON, J. C., 1997. Lower to Middle Devonian radiolarian assemblages from the Gamilaroi Terrane, Glenrock Station, NSW, Australia. *Marine Micropalaeontology* 30: 225–250.

SWEET, W. C., 1988. *The Conodonta: morphology, taxonomy, paleoecology and evolutionary history of a long-extinct animal phylum.* Clarendon Press, Oxford, 212 pp.

TALENT, J. A., 1989. Transgression–regression pattern for the Silurian and Devonian of Australia. In *Pathways in geology—essays in honour of Edwin Sherbon Hills*, R. W. Le Maitre, ed., Blackwells, Carlton, 201–219.

TALENT, J. A. & MAWSON, R., 1994. Conodonts in relation to the age and environmental framework of the Burdekin Basin (mid-Devonian), north-eastern Australia. *Courier Forschungsinstitut Senckenberg* 168: 61–81.

TELFORD, P. G., 1975. Lower and Middle Devonian conodonts from the Broken River Embayment, North Queensland, Australia. *Special Paper in Palaeontology* 15: 1–96.

WEDDIGE, K., 1977. Die Conodonten der Eifel-Stufe in Typusgebiet und in benachbarten Faziesgebieten. *Senckenbergiana lethaea* 58: 271–419.

WHITE, A. H., 1964. *Geological map of New England 1:100 000, Attunga sheet (No. 321) with marginal text.* University of New England, Armidale.

WHITE, A. H., 1965. The stratigraphy and structure of the Upper Palaeozoic sediments of the Somerton–Attunga district, NSW. *Proceedings of the Linnaean Society of New South Wales* 89: 203–217.

WINCHESTER-SEETO, T. & PARIS, F., 1995. Latest Givetian and Frasnian chitinozoans from Australia, France and Pakistan in relation to conodont zonation. *Courier Forschungsinstitut Senckenberg* 182: 451–473.

WRIGHT, A. J., PICKETT, J. W., SEWELL, D., ROBERTS, J. & JENKINS, T. B. H., 1990. Corals and conodonts from the Late Devonian Mostyn Vale Formation, Keepit, New South Wales. *Association of Australasian Palaeontologists Memoir* 10: 211–254.

ZIEGLER, W., 1966. EinenVerfeinerung der Conodontengleiderung am der Grenze Mittel-/Oberdevon. *Fortschrifte der Geologie von Rheinland-Westfalen* 9: 647–676, 6 pls.

ZIEGLER, W., ed., 1973. *Catalogue of Conodonts I*, E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, 504 pp, 27 pls.

ZIEGLER, W., ed., 1977. *Catalogue of conodonts III*, E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, 574 pp, 39 pls.